(12) UK Patent Application (19) GB (11) 2 316 246 (13) A

(43) Date of A Publication 18.02.1998

(21) Application No 9716377.8

(22) Date of Filing 01.08.1997

(30) Priority Data
(31) 08695154 (32) 05.08.1996 (33) US

(71) Applicant(s)
BF Goodrich Avionics Systemc Inc
(Incorporated in USA - Michigan)
5353 52nd Street S.E., Grand Rapids, Michigan 49588, United States of America

(72) Inventor(s)
Richard King Bodkin

(74) Agent and/or Address for Service
Mathisen Macara & Co
The Coach House, 6-8 Swakeleys Road, Ickenham, UXBRIDGE, Middlesex, UB10 8BZ, United Kingdom

(51) INT CL^6
H05B 41/38 41/42 // G05D 23/19 25/02, G09G 3/34

(52) UK CL (Edition P)
H2H HB8 HLD62 HLD631 H20B H22B H23Y H25G H25Q H7B H72
G3R RA37 RA625 RBK RBU RB352 RB4723
U1S S1839 S1925 S2285

(56) Documents Cited
GB 2269948 A EP 0086664 A1 WO 82/03744 A1
US 5175471 A US 4749916 A US 4682083 A
US 4544862 A
IBM Technical Disclosure Bulletin, Vol.34, No.4A, September 1991, pages 109-111

(58) Field of Search
UK CL (Edition O) G3R RBK, H2H HLD52 HLD62 HLD631
INT CL^6 G05D 25/02, G09G 3/34, H05B 41/38 41/39 41/392 41/40 41/42
ONLINE : WPI

(54) Intensity control for fluorescent lamps

(57) The intensity of a fluorescent lamp, particularly an LCD backlight in an aircraft, is controlled by a device coupled between an AC power supply 24 and the lamp 10. The device may be connected in series with the lamp (Fig.2) or particularly in shunt with the lamp. The lamp 10 may be driven by a self oscillating resonant inverter 24 operating at about 70KHz and having an output transformer 70 with secondaries 80a, 80b coupled to the lamp via ballast capacitors 28. A further secondary 82 provides heater power to the lamp filaments 32 via a switch 34a and a transformer 30. Lamp intensity may be controlled by pulse rate modulation, or particularly PWM of a switch 40 in shunt with the lamp 10. A PWM control signal 44 for switch 40 is synchronised with the frequency of the inverter 24 by means of a zero crossing detector 86, divider 52 and ramp generator 88 which produces a ramp signal 90 at 140Hz. A comparator 92 compares the ramp 90 with an error signal 96 produced by combining an external intensity command 69 and a lamp intensity feedback signal from a light sensor 58. Synchronising the operation of switch 40 with the inverter reduces flicker. Very low intensity control is improved by controlling switch 40 so that it turns off slowly. Heater power to the filaments 32 may also be controlled by PWM of switch 34a. The lamp 10 may be maintained at its optimum temperature by means of a heater 26 controlled in response to a temperature sensor (Fig.3B). The lamp intensity control may have only two states: a bright state with the switch 40 nearly fully off (duty cycle near 0%), and a dim state with the switch 40 nearly fully on (duty cycle near 100%).

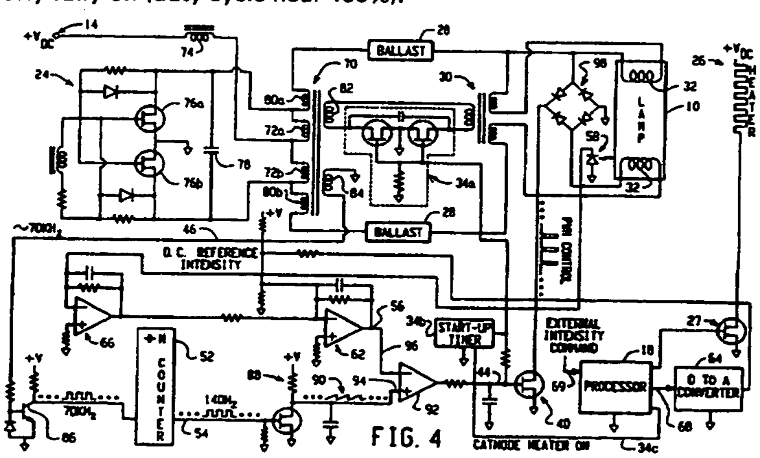


FIG. 4

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

GB 2 316 246 A

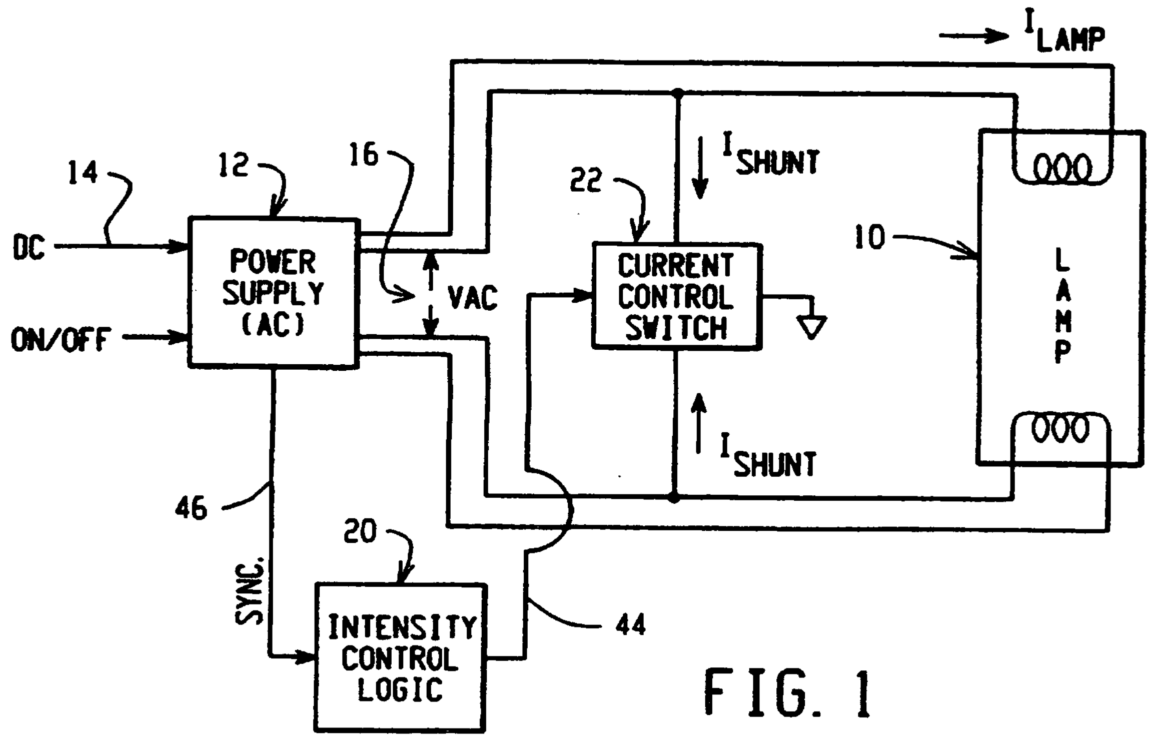

I LAMP
14
12
16
22
I SHUNT
10
DC
POWER SUPPLY (AC)
VAC
CURRENT CONTROL SWITCH
LAMP
ON/OFF
I SHUNT
46
20
SYNC.
44
INTENSITY CONTROL LOGIC

FIG. 1

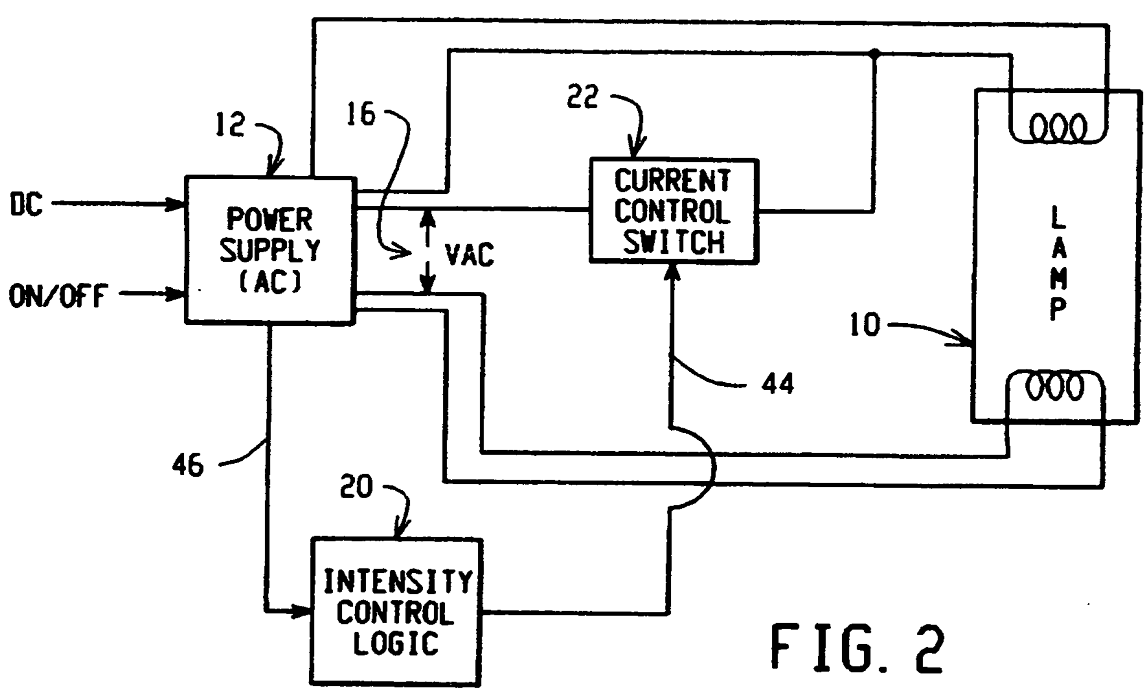

12
16
22
DC
POWER SUPPLY (AC)
VAC
CURRENT CONTROL SWITCH
LAMP
ON/OFF
10
44
46
20
INTENSITY CONTROL LOGIC

FIG. 2

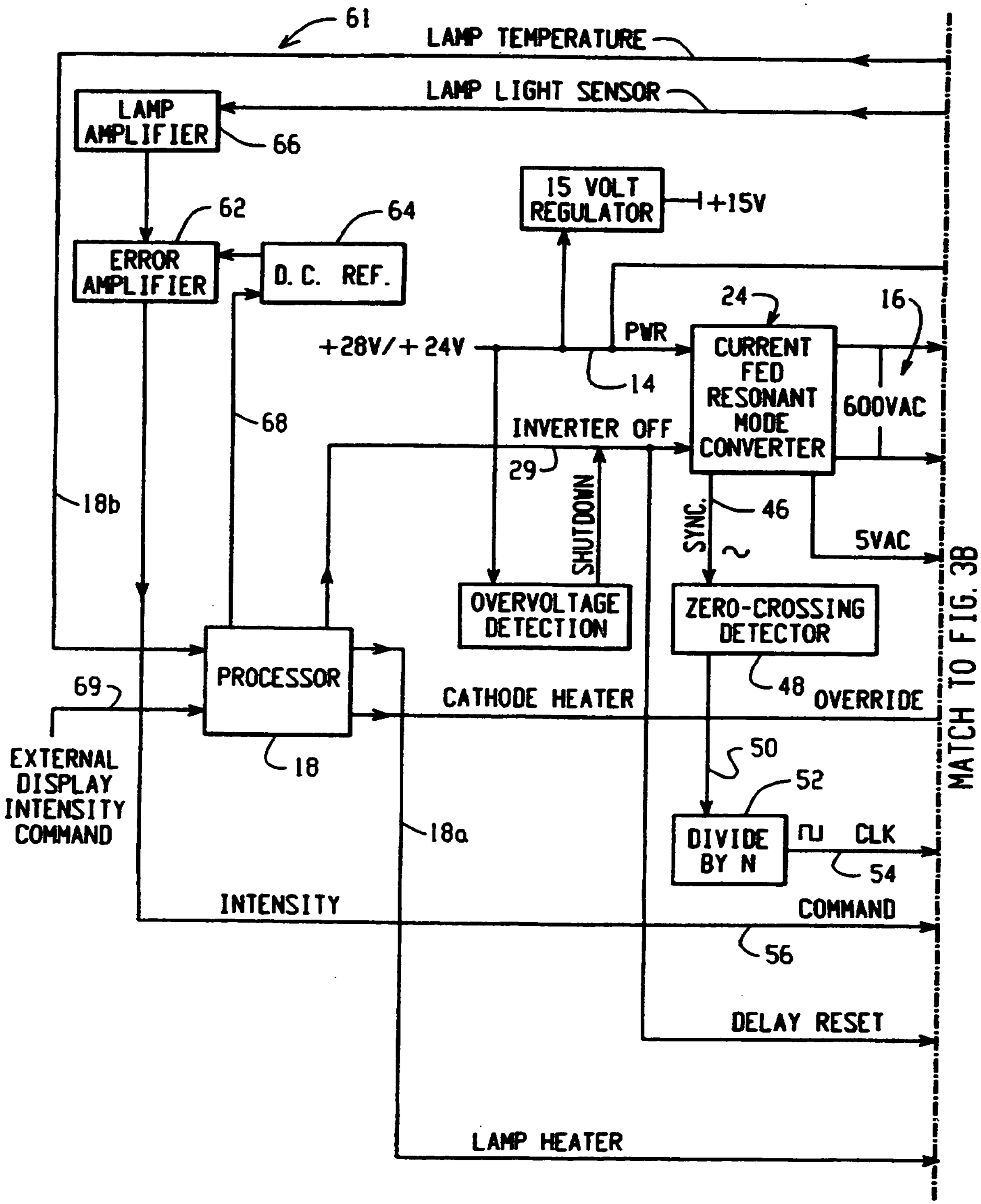
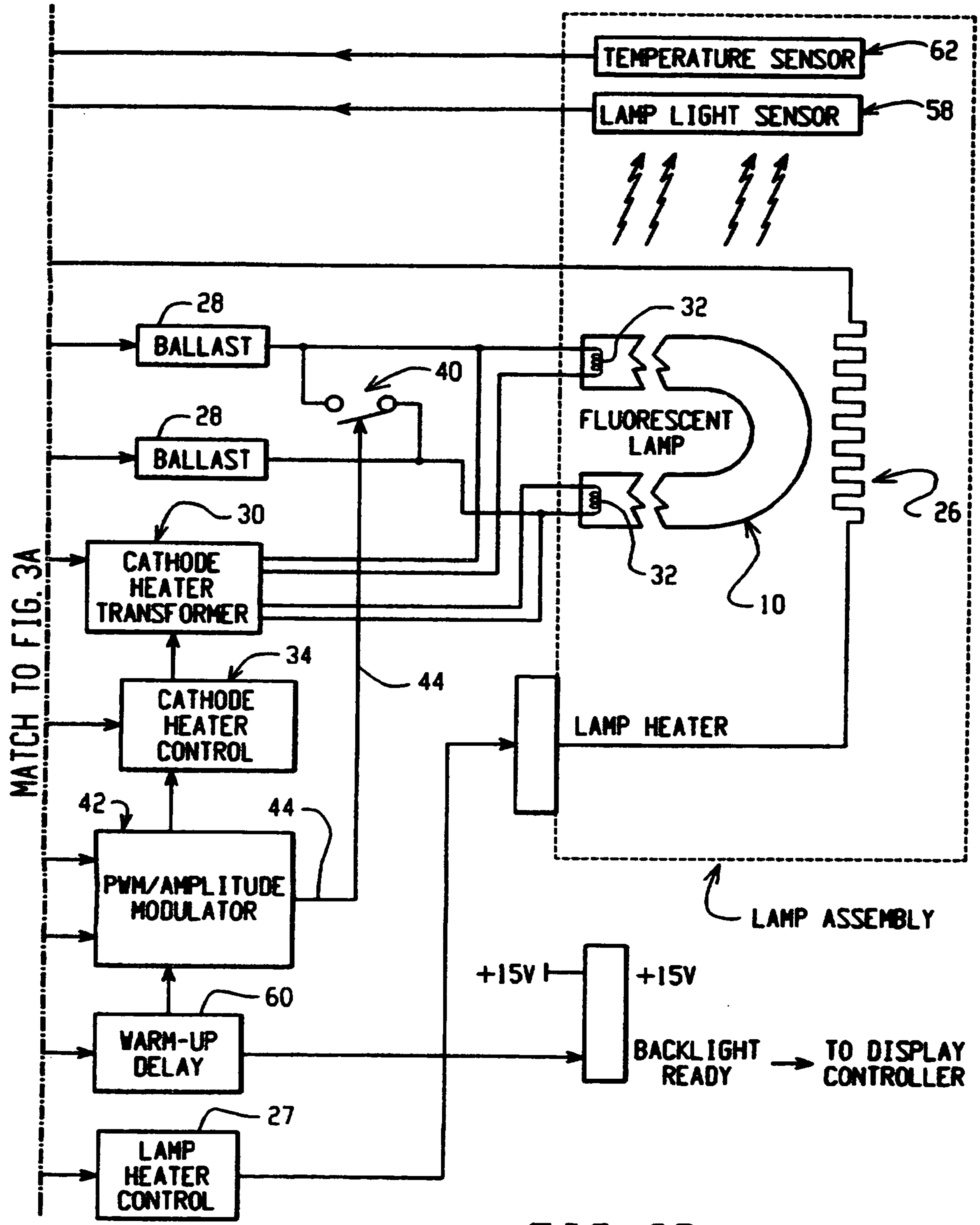

61
LAMP TEMPERATURE
LAMP LIGHT SENSOR
LAMP AMPLIFIER
66
62
64
15 VOLT REGULATOR
+15V
ERROR AMPLIFIER
D.C. REF.
24
16
PWR
+28V/+24V
14
CURRENT FED RESONANT MODE CONVERTER
600VAC
68
INVERTER OFF
29
SHUTDOWN
SYNC.
46
18b
5VAC
OVERVOLTAGE DETECTION
ZERO-CROSSING DETECTOR
PROCESSOR
69
CATHODE HEATER
48
OVERRIDE
EXTERNAL DISPLAY INTENSITY COMMAND
18
50
52
18a
DIVIDE BY N
CLK
54
INTENSITY
COMMAND
56
DELAY RESET
LAMP HEATER
MATCH TO FIG. 3B

FIG. 3A



MATCH TO FIG. 3A
TEMPERATURE SENSOR
62
LAMP LIGHT SENSOR
58
28
BALLAST
28
BALLAST
40
32
FLUORESCENT LAMP
32
10
26
30
CATHODE HEATER TRANSFORMER
34
CATHODE HEATER CONTROL
44
LAMP HEATER
42
44
PWM/AMPLITUDE MODULATOR
LAMP ASSEMBLY
+15V
+15V
60
WARM-UP DELAY
BACKLIGHT READY
TO DISPLAY CONTROLLER
27
LAMP HEATER CONTROL

FIG. 3B

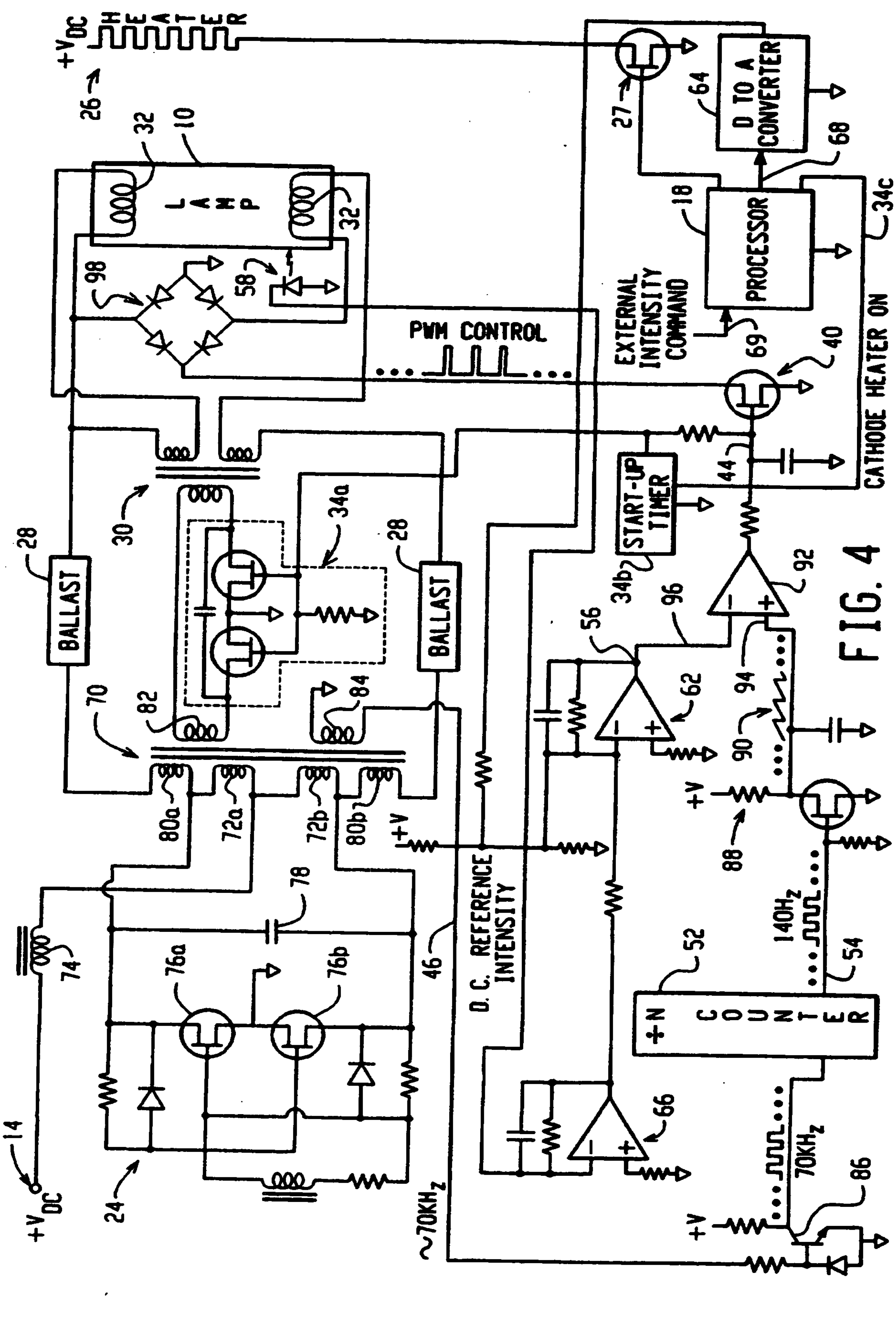
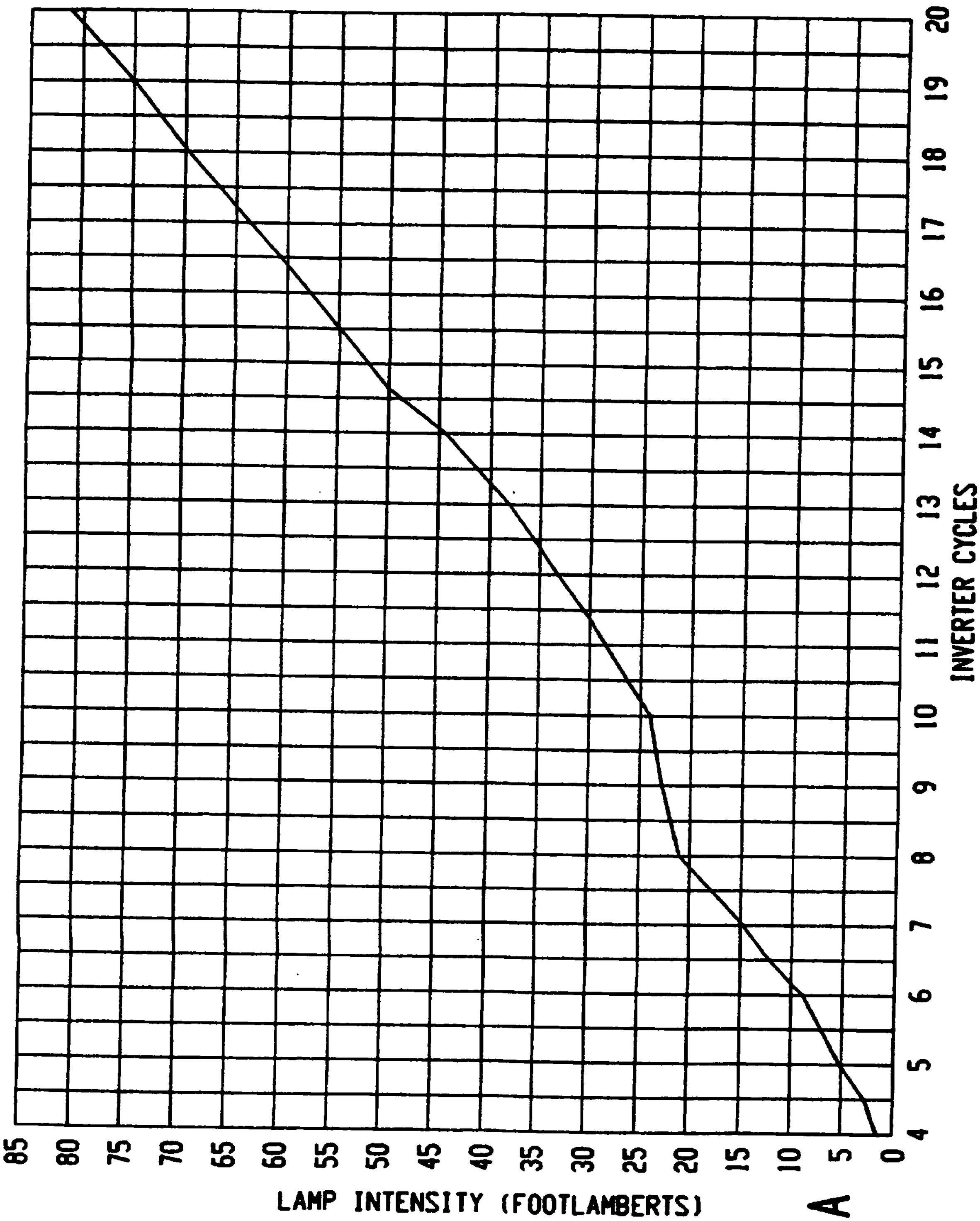
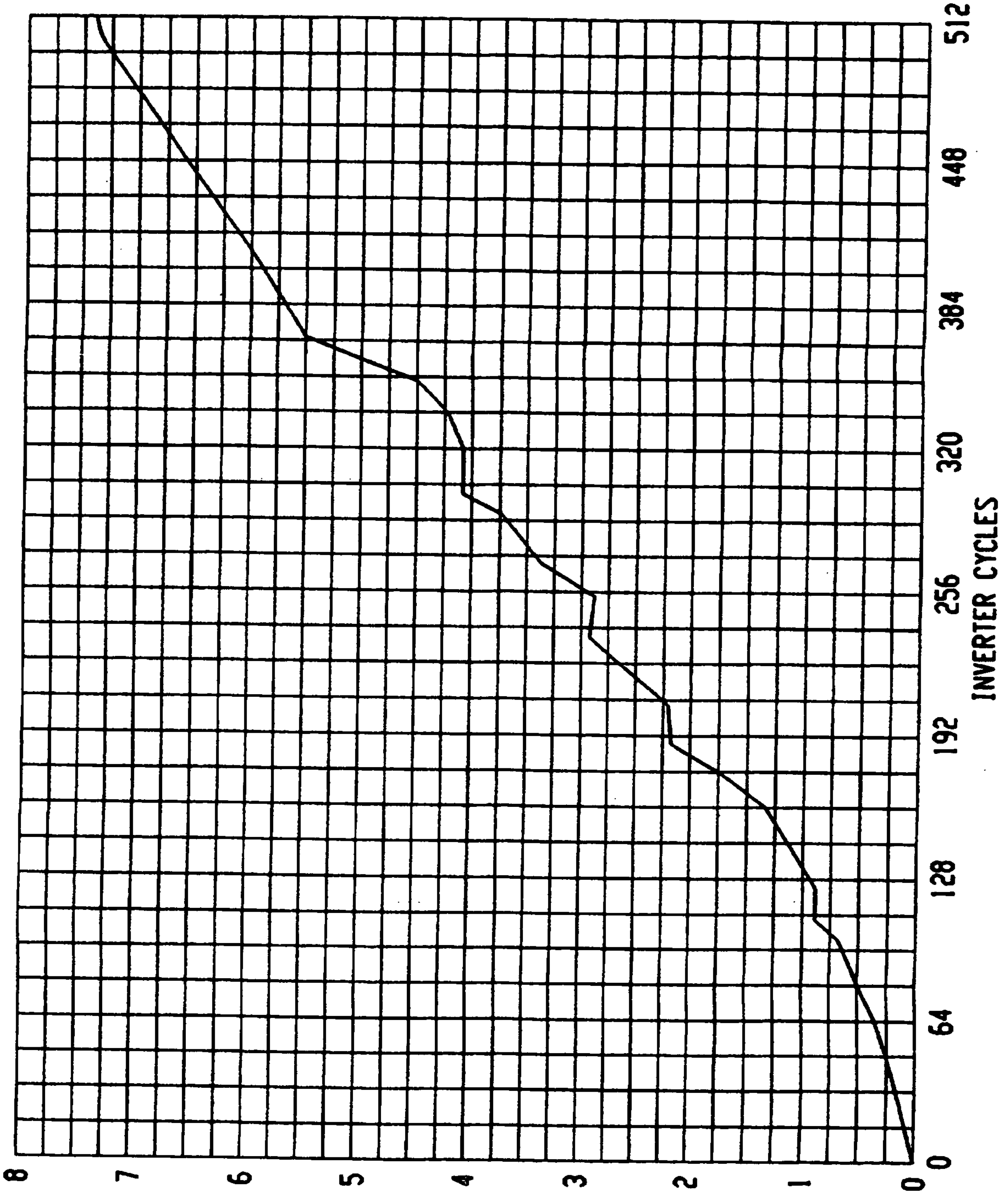

+V_DC
HEATER
26
32
10
LAMP
32
98
58
PWM CONTROL
27
64
D TO A CONVERTER
68
18
PROCESSOR
34c
EXTERNAL INTENSITY COMMAND
69
40
CATHODE HEATER ON
28
BALLAST
30
34a
44
START-UP TIMER
34b
28
BALLAST
56
96
92
62
94
90
+V
88
70
82
84
80a
72a
72b
80b
+V
D.C. REFERENCE INTENSITY
46
78
74
76a
76b
14
+V_DC
24
~70KHz
52
÷N
COUNTER
54
140Hz
66
70KHz
86
+V

FIG. 4



INVERTER CYCLES
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
LAMP INTENSITY (FOOTLAMBERTS)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85

FIG. 5A



0
64
128
192
256
320
384
448
512
INVERTER CYCLES
0
1
2
3
4
5
6
7
8
LAMP INTENSITY (FOOTLAMBERTS)
(THOUSANDS)

FIG. 5B

Title: INTENSITY CONTROL FOR FLUORESCENT LAMPS

BACKGROUND OF THE INVENTION

The invention relates generally to apparatus and methods for controlling intensity of a fluorescent lamp. More particularly, the invention relates to controlling the lamp intensity by controlling the current to the lamp without interrupting the operation of the power supply used to energize the lamp.

Fluorescent lamps are typically energized by a power source that delivers a high AC starting voltage to the lamp electrodes. In aircraft instrumentation applications, the power source typically is an AC inverter that operates from a DC voltage input source. After the lamp is lit, the voltage across the lamp drops due to the relatively low impedance of the arc. The intensity of the lamp is a function of the amount of current the lamp conducts, with the maximum intensity being limited by the lamp ballast components and the applied DC voltage input to the inverter.

Many applications that use fluorescent lamps require the capability to dim the lamp. This is particularly so with aircraft instrumentation that use fluorescent light as back light in a liquid crystal display. A pilot must be able to read the instrument display under the various operating conditions of the aircraft, from bright direct sunlight to essentially total darkness. This means that the fluorescent lamp must be able to produce high output intensity under bright ambient conditions, and very low intensity under dark ambient conditions. Known techniques for dimming fluorescent lamps include lowering the input DC voltage level, and turning the inverter off and on. However, these techniques are not adequate for very low level intensity control.

The objectives exist, therefore, for improved, reliable and efficient apparatus and methods for controlling the intensity of a fluorescent lamp, particularly for controlling very low intensity levels.

SUMMARY OF THE INVENTION

The present invention contemplates, in one embodiment, an intensity control apparatus that includes a fluorescent lamp; a power supply with an output connected to the lamp; and a control circuit, in series with the power supply output, that operates to control light intensity from the lamp by changing current through the lamp.

The present invention also contemplates the methods embodied in the use of such apparatus, as well as in another embodiment, a method for controlling intensity of a fluorescent lamp, including the steps of:

a) producing an ac voltage at the output of a power supply to energize the lamp; and

b) shunting current away from the lamp to reduce the output intensity of the lamp.

These and other aspects and advantages of the present invention will be readily understood and appreciated by those skilled in the art from the following detailed description of the preferred embodiments with the best mode contemplated for practicing the invention in view of the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a simplified functional block diagram of an intensity control circuit for a fluorescent lamp in accordance with the invention;

Fig. 2 is a simplified functional block diagram of an alternative embodiment of an intensity control circuit for a fluorescent lamp in accordance with the invention;

Figs. 3A and 3B are a more detailed functional block diagram of one embodiment of the invention illustrated in Fig. 1;

Fig. 4 is a detailed schematic diagram of one embodiment of an intensity control circuit in accordance with the present invention; and

Figs. 5A and 5B are representative graphs that illustrate how lamp intensity can be finely controlled in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

With reference to Fig. 1, the general concepts of the present invention are illustrated in an exemplary manner. A fluorescent lamp 10 is energized with electrical power from an AC power supply 12. In the exemplary embodiments described herein, the fluorescent lamp is of the type commonly used for back light in aircraft instrumentation such as, for example, liquid crystal displays. Therefore, the power supply 12 is illustrated as an inverter that converts a DC input voltage 14 into an AC output voltage 16 to drive the lamp 10. In these embodiments, the lamp 10 is driven differentially by the power supply 12, but this is a matter of design preference and not a requirement for operation of the invention. The particular type of lamp 10 illustrated herein is commonly referred to in the art as a hot cathode lamp. All these exemplary descriptions herein should not be construed in a limiting sense. The present invention can be used with many different power supply designs and configurations, as well as different types of fluorescent lamps, such as cold cathode lamps, for example.

The present invention is directed to an intensity control technique for the lamp 10 that includes, in a preferred embodiment, an intensity control logic circuit 20 and a current control switch circuit 22. The control circuit 20 can be realized in many different ways including analog and/or digital configurations. In the exemplary embodiments described hereinafter, the control circuit 20 is based on the use of a programmable controller, such as a microprocessor, for example.

In accordance with one aspect of the invention, intensity control, and particularly very low level intensity control, is performed by using the switch circuit 22 to change the amount of current through the lamp 10. In the preferred embodiment, the switch circuit 22 is in shunt with the lamp 10 (as illustrated in Fig. 1), and when the switch circuit 22 is activated into an "on" condition, the circuit 22 shunts current from the lamp 10, thereby reducing the lamp 10 output

intensity. When the switch circuit 22 is changed to its "off" condition, full current is available to the lamp 10. Thus, the switch circuit 22 operates to control, regulate or change the average current through the lamp 10, thereby controlling the lamp intensity.

In accordance with another aspect of the invention, average drive current through the lamp 10 is controlled by modulating the switch circuit 22 such that the switch 22 redirects current away from the lamp 10 and back to the power supply 12. By changing the modulation duty cycle or rate of the switch circuit 22, the average current through the lamp 10 is increased or decreased by respectively decreasing or increasing the current through the switch circuit 22. The modulation can be implemented in different ways, including, for example, pulse width modulation and pulse rate modulation techniques, to name just two examples.

In the present embodiment, a pulse width modulated (PWM) signal is used to control the on/off condition of the switch circuit 22. The average current through and intensity of the lamp 10 is controlled by the duty cycle of the PWM signal by controlling the ratio of "on" time to "off" time of the switch circuit 22 which is in shunt with the lamp 10. For example, increasing the duty cycle causes the switch circuit 22 to be in an "on" condition for a longer time period for each cycle of the PWM signal, thus increasing the average current shunted from the lamp 10 and concomitantly reducing the lamp 10 intensity.

In accordance with another aspect of the invention, the current control function is implemented on the output side of the power supply 12. Typical prior approaches to controlling intensity of the lamp 10 involved changing the operating parameters of the inverter 12. For example, to dim the lamp 10 to a lower intensity, the input DC voltage 14 could be dropped, or operation of the power supply 12 could be interrupted. These techniques, however, are not especially effective for very low intensity control without adding substantial complexity to the design of the power supply 12.

For very low lamp intensity, it may be necessary to reduce the current flow through the lamp to only a few or even a single cycle, for example. A typical inverter cannot be easily controlled to effect such low current output because the inverter is a reactive circuit that stores energy that must be dissipated. The lamp 10 also exhibits a decay characteristic that prevents the lamp from fully extinguishing for a minimum time after the inverter is interrupted. Reducing the DC input voltage 14 may adversely affect operation of the inverter or reduce the ability, for example, to continuously heat the lamp 10 cathodes. Furthermore, when the power supply 12 is interrupted, or when the DC input voltage is reduced, the lamp 10 is still susceptible to stray noise that can be sufficient to keep the lamp 10 intensity brighter than desired.

The intensity control technique implemented with the present invention overcomes these drawbacks of the prior efforts because operation of the power supply 12 is not interrupted. By shunting the supply current away from the lamp 10, the power supply 12 can continue to operate uninterrupted and be used, for example, to continuously heat the lamp cathodes. Shunting the current away from the lamp does not significantly reduce the efficiency of the system because the power supply 12 is a resonant circuit. The shunt arrangement implemented by the switch circuit 22 simply provides a low impedance recirculation path for the resonant current from the power supply 12. Therefore, power loss during the time period when the switch 22 is "on" is low, with most of the power dissipation occurring in the lamp 10 itself when the switch 22 is "off".

The shunt configuration illustrated in Fig. 1 also provides the benefit of a low impedance path in parallel with the lamp 10 during very low intensity operation. This shunt path thus makes lamp 10 much less susceptible to stray capacity or current that could otherwise tend to keep the lamp lit at an undesired brighter intensity. Operation of the shunt configuration also reduces the effect of slow lamp decay

because the drive current is immediately pulled away from the lamp 10.

In an alternative embodiment shown in Fig. 2, the basic elements are the same and therefore the same reference numerals are used and the description thereof need not be repeated. The configuration of the elements, however, is now in the form of a series connection of the switch circuit 22 between the lamp 10 and the power supply 12. The switch circuit 22 is still used to interrupt current to the lamp 10, but is accomplished in this configuration by opening the current path between the power supply 12 and the lamp 10. Although this alternative configuration operates for low intensity control, it may in some cases exhibit higher sensitivity to stray noise and slow decay of the lamp 10 than the embodiment of Fig. 1 because of the lack of a shunt path. This embodiment also may in some cases tend to exhibit higher noise spikes when the current to the lamp is interrupted due to the inductance characteristics of the power supply 12. However, the approach of Fig. 2 is still an improvement over the prior techniques of interrupting the power supply 12 or lowering the DC input voltage, because the embodiment of Fig. 2 still permits very fine control over the lamp 10 intensity.

The reference to a "series" connection in Fig. 2 is specifically in the context of a series connection of the switch circuit 22 between the power supply 12 and the lamp 10. It will be noted that in Fig. 1, the switch circuit 22 is also in series with the power supply 12, however, in that configuration the switch circuit 22 is also in shunt with the lamp 10 and serves to bypass current away from the lamp 10 and recirculate resonant power back to the power supply 12.

Having described the basic concepts of the present invention, reference is next made to Figs. 3A and 3B for a more detailed block diagram of the preferred embodiment generally described with respect to Fig. 1.

In the embodiment of Figs. 3A and 3B, the power supply 12 is realized in the form of a current fed self-oscillating sinusoidal inverter 24. DC input voltage 14 can be supplied

from a battery, for example, or other suitable power supply on the aircraft. This DC voltage can also be used to energize a lamp heater 26 associated with the lamp 10. The heater 26 can be used to maintain the lamp at its optimum temperature for producing light, as is well known. A heater control circuit 27 can be provided for separate control of the lamp heater 26 operation. The heater control circuit 27 is controlled by an output 18a from a processor 18, which can be any convenient and suitable digital processor or control circuit. Those skilled in the art will appreciate that different digital and analog control circuits can be used to carry out the present invention, with the descriptions herein being exemplary. The processor 18 is programmed using conventional programming techniques, and carries out various control and analysis functions as will be apparent from the following descriptions of the operation of the invention.

In this embodiment, the inverter 24 produces a sinusoidal output voltage 16 of about 600 VAC at a frequency of about 70 kHz. The voltage across the lamp 10 drops to about 70-90 VAC when the lamp turns on. The output voltage and frequency of the inverter 24 are exemplary, and those skilled in the art will readily appreciate that these parameters will be determined for each application based on the lamp 10 operating characteristics and power requirements. The design of the inverter circuit 24 can be selected from many conventional designs that are well known to those skilled in the art. Although not shown in Figs. 3A and 3B, the output of the inverter 24 is realized in the form of a secondary winding of a power transformer in the inverter 24 circuit, and this secondary is connected across the lamp 10 so as to drive the lamp 10 differentially. The inverter 24 output 16 is connected to the lamp 10 by a pair of ballast capacitors 28 or other suitable ballast elements. The ballast elements 28 operate to limit peak current through the lamp 10, as is known. An on/off control signal 29 can be provided to disable the inverter 24 if so required.

In this embodiment, the lamp 10 is a hot cathode lamp, and a small transformer 30 of the inverter 24 is used to provide a low AC voltage to heat the lamp cathodes 32. Because the intensity control function of the instant invention is accomplished on the output side of the inverter 24, the hot cathode power can be continuously applied to the lamp 10 cathodes. A cathode heater override control circuit 34 can be provided if required, under control of the processor 18 as illustrated. This heater control circuit 34 can also be used with a PWM control signal for controlling the cathode heater function if required.

A high speed switch 40 is disposed in shunt with the lamp 10. In this embodiment, the switch 40 can be, for example, a fast switching FET switch, such as part no. MTB1N100E available from Motorola. When closed, the switch 40 shunts drive current away from the lamp 10 and essentially recirculates resonant power back to the inverter 24. When the switch 40 is open, drive current from the inverter 24 flows through the lamp 10 as determined by the ballast elements 28, the lamp 10 characteristics and the voltage supply from the inverter 24. By controlling the duty cycle of the switch 40, the intensity of the lamp 10 can be precisely controlled, even at very low intensities, without interruption of the inverter 24.

The switch 40 duty cycle is controlled using a PWM circuit 42, which produces a PWM gate control signal 44 for the switch 40. In accordance with another aspect of the invention, the PWM drive signal 44 is synchronized with the inverter 24 output frequency. By having the PWM signal 44 synchronous with the inverter 24 frequency, low frequency beat signals are prevented which could be visible to the human eye as flicker in the back light display.

A secondary winding tap is used to produce a low voltage sinusoidal synchronizing signal 46 from the inverter 24, which is at the same frequency as the inverter AC voltage output 16 used to drive the lamp 10. The synchronizing signal 46 is input to a zero crossing detector circuit 48, which produces

a corresponding square wave output 50 at the frequency of the inverter 24. This square wave output 50 is then divided down using a counter 52 to a lower frequency square wave output 54, in this case about 140 hertz. The output frequency from the counter 52 is selected to be well above 30 hertz, which would be visible to the human eye.

The low frequency output 54 from the counter 52 is input to the PWM modulator 42. The PWM modulator 42 circuit can be conventional in design to produce the PWM control signal 44. In this embodiment, the PWM gate control signal 44 is generated by first integrating the low frequency square wave signal 54 to produce a saw tooth shaped signal, and then comparing the saw tooth signal with an intensity reference signal 56. The PWM signal 44 thus is "high" whenever the saw tooth signal is above the reference, and "low" whenever the saw tooth signal is below the reference. By changing the reference signal 56 level, the duty cycle of the gate control signal 44 is correspondingly changed. Those skilled in the art will appreciate that the notations herein to logic "high" and "low" as well as "open" and "closed" switch states, and so on, are simply references for purposes of explanation, and that the actual implementation of the logic may use opposite control states.

If so required, a lamp warm up delay circuit 60 can be used to inhibit operation of the PWM circuit 42 until the heater 26 and cathodes 32 are sufficiently warm for proper operation of the lamp 10. The delay can be timed, or also based on a lamp temperature sensor 62. The sensor 62 output signal is provided as an input 18b to the processor 18 which prevents operation of the lamp until the temperature sensor 62 indicates the lamp is warm enough for operation.

The intensity reference signal 56 is used to set the PWM duty cycle of the switch 40 to control the intensity of the lamp 10 as noted above. This intensity control can be implemented in as simple a form as having two states: a "bright" condition with the switch 40 nearly full off (corresponding, for example, to a duty cycle of near or at 0%

of the control signal 44 and the switch 22) and a "dim" condition with the switch 40 nearly full on (corresponding to a duty cycle of near or at 100%). However, any other degree of intensity control can be implemented in between full brightness and minimum intensity by simply adjusting the duty cycle of the switch control signal 44 as required to achieve the desired intensity. It will be appreciated that the fineness or resolution of the degree of control over the lamp intensity will be determined in part by the designed resolution of the PWM control signal 44, i.e. the extent to which the pulse width of the PWM signal 44 can be incrementally changed in response to a command signal such as the intensity reference signal 56.

The intensity command signal 56 is controlled by the processor 18 by use of a closed loop feedback intensity control circuit 61. An error amplifier 62, such as a conventional differential amplifier, receives a first input from a controllable DC voltage source 64 and another input from a light sensor amplifier 66. The sensor amplifier circuit 66 amplifies and conditions the output signal from a lamp intensity sensor 58. The intensity sensor 58, can be realized in the form of a photodiode, for example. In this case, the intensity feedback signal from the sensor 58 can be used to offset or otherwise adjust the reference level 56 for the PWM comparator so as to produce a duty cycle for the PWM control signal 44 that achieves and/or maintains the selected intensity output level. The error amplifier 62 controls the intensity control reference signal 56 to the modulator 42 based on the error differential between the commanded lamp intensity as represented by the reference voltage from the source 64 and the actual lamp intensity detected by the sensor 58. Thus, the intensity control signal 56 is used to adjust the duty cycle of the PWM modulator output signal 44 that drives the gate of the switch 40. The processor 18 controls the voltage reference level from the source 64 to the error amplifier 62 using a control signal 68. In this manner, the processor 18 can command or control a change in the output

intensity from the lamp 10. As part of this control, the processor 18 can receive an external intensity control input signal 69, such as from a display control circuit, a manual intensity setting switch, and so on to name a few examples.

By using a fast switching device 40, very low intensity control of the lamp 10 can be effectively controlled by using a very short duration "off" time period of the control signal 44 (corresponding to a high duty cycle), even on the order of allowing a few cycles, one cycle or less than one cycle of the high frequency AC current to pass through the lamp 10. The frequency of the PWM control signal 44 need only be high enough to avoid being detectable to the human eye, such as, for example, 140 hertz.

In the present example, very fine control of the lamp 10 intensity is achieved. The 70 kHz drive frequency is 500 times higher than the 140 Hz frequency of the PWM control signal. Thus, 500 cycles of the lamp drive current occur for each cycle of the control signal 44. Thus, for example, a 1% duty cycle would pass five cycles of the lamp 10 drive current. Figs. 5A and 5B illustrate in an exemplary manner the nature of the very fine intensity control that can be achieved using the present invention. Fig. 5A shows lamp intensity vs. inverter 24 output cycles (used for the drive current through the lamp 10) for very low cycle numbers. Fig. 5B illustrates the same relationship at higher inverter 24 cycles through the lamp 10. The invention facilitates very fine control over the number of cycles passed through the lamp 10 (conversely shunted away from the lamp 10) thus producing a stable and high resolution control of the lamp intensity from maximum intensity to very very low intensity levels.

Although not shown in the drawings, the lamp 10 can also be connected to a display controller circuit that controls the overall liquid crystal display, and can be interfaced therewith as required to provide and receive override and other control signals for the back light lamp 10 control as needed.

With reference next to Fig. 4, a detailed schematic of an intensity control circuit according to the invention is illustrated. For clarity and ease of explanation, Fig. 4 illustrates only those components which embody the intensity control function of the present invention, as well as some of the components of the inverter 24, and is not intended to be an all inclusive schematic of a lamp control circuit.

The inverter 24 as stated can be conventional and is well known. In this embodiment, the inverter 24 includes a step up power transformer 70 that has a number of primary and secondary windings. Two primary windings 72a and 72b are connected at one end to the DC input voltage 14 via an inductor 74. The other ends of the primary windings 72a and 72b are respectively connected to FET transistors 76a and 76b and a capacitor 78. The transformer 70 secondary drive winding is connected to the gates of the FET transistors 76a and 76b to complete the self-oscillating current fed sinusoidal inverter 24 configuration. The frequency of the inverter 24 is determined by the resonant frequency of the capacitor 78 and the primary windings 72a and 72b. A pair of autotapped secondary windings 80a and 80b are connected to the lamp 10 cathodes via the ballast elements 28 as previously described herein. The ballast elements 28 and the secondary windings 80a and 80b will also influence the resonant frequency of the inverter 24. A secondary winding 82 of the power transformer 70 is connected to the cathode heater transformer 30 that has two secondary windings, each connected across a respective cathode 32 of the lamp 10 as illustrated. The operation of the cathode heating function is controlled by the cathode heater control circuit 34 (see Fig. 3), which in the embodiment of Fig. 4 can include a switch circuit 34a to control power to the cathode transformer 30, and a start-up timer circuit 34b that actuates heating of the cathodes 32 before the lamp is started. The timer circuit 34b can produce an output signal 34c to the processor 18 to indicate that the cathode heater is on, and during this heating time, the switch

40 is turned fully on to shunt drive current away from the lamp 10.

Another secondary winding 84 of the power transformer 70 is used to produce the low voltage synchronizing signal 46. The zero crossing detector 48 is realized in the form of a transistor switch 86 with its collector being connected to the input of a dividing counter 52. The counter 52 divides the zero detector output frequency down to a low frequency square wave signal 54 that is synchronous with the inverter 24 output voltage frequency that drives the lamp 10. The low frequency square wave output of the counter 52 is input to an integrator 88 that produces a saw tooth signal 90 at an input 94 of a differential comparator circuit 92.

The other input 96 of the comparator 92 is connected to the output of the error amplifier 62, realized in this case in the form of an operational amplifier in a summing amplifier configuration. The output of the amplifier 62 is the intensity control reference signal 56 described herein before. The comparator 92 output is thus a rectangular pulse signal having a duty cycle determined by the percentage of the saw tooth signal 94 that is above the reference input 96. The comparator 92 output is thus a pulse width modulated signal 44 used to drive the control gate of the high voltage fast switching FET switch 40.

The summing amplifier 62 receives one input from the lamp sensor amplifier 66 which conditions and inverts the output signal from the lamp sensor 58. The summing amplifier 62 also receives a DC reference input from the output of the reference circuit 64 realized in the form of a digital to analog converter. The processor 18 issues a digital word to the converter 64 which produces a corresponding DC voltage provided to the amplifier 62 based on an external commanded intensity level 69 for the lamp. Note that the processor 18 intensity control function (such as dimming or brightening), in this embodiment, is accomplished as part of the closed loop feedback control circuit 61 for the lamp intensity control.

In accordance with another aspect of the invention, the switch 40 is turned off slowly. This mode of operation of the switch 40 thus permits the switch 40 to change states without sharp rising and falling edges and improves very low intensity control of the lamp 10. However, in some applications, operation of the switch 40 with sharply defined transitions will produce acceptable control of the lamp intensity.

The switch 40 is connected in shunt with the lamp 10 across a full bridge rectifier circuit 98 so that when the switch 40 is conducting, the AC current produced by the inverter 24 is shunted away from the lamp 10 and returned to the inverter 40 with very low power loss as this current is simply resonant current of the inverter 24. The duty cycle of the switch 40 thus determines the average amount of current that is shunted from the lamp 10 and therefore determines the average output intensity of the lamp 10. By pulsing the switch 40 on for very short periods of time, stable very low intensity control of the lamp 10 is realized. Those skilled in the art will appreciate that the switch 40 and the bridge circuit 98 form a simple embodiment of an AC switch, and that other AC switch designs can also be used, based on the degree of control over the lamp intensity needed.

The invention thus provides apparatus and methods for controlling intensity of a fluorescent lamp, especially very low intensity control, without interrupting the operation of the power supply used to drive the lamp. The invention thus achieves a very fine control over low intensity operation of the lamp with the use of a conventional and simple power supply design.

While the invention has been shown and described with respect to specific embodiments thereof, this is for the purpose of illustration rather than limitation, and other variations and modifications of the specific embodiments herein shown and described will be apparent to those skilled in the art within the intended spirit and scope of the invention as set forth in the appended claims.

CLAIMS

1. Intensity control apparatus for a fluorescent lamp comprising: a power supply with an output connectable to the lamp; and a control circuit, in series with said output, which operates to control light intensity from the lamp by changing current through the lamp.

2. The apparatus of claim 1, wherein said control circuit reduces average current through the lamp to lower the light intensity.

3. The apparatus of claim 1 or 2, wherein said control circuit comprises a switch, in shunt with the lamp, that conducts current from said power supply to reduce average current to the lamp to lower lamp intensity.

4. The apparatus of any preceding claim, wherein said switch comprises a solid state switch and means for actuating said switch with a pulse modulated signal to vary the current through the switch.

5. The apparatus of claim 4, wherein said power supply produces an AC voltage, said pulse modulated signal being synchronous with said AC voltage.

6. The apparatus of claim 4 or 5, wherein said switch can be switched off for a time period as short as one cycle of said AC voltage.

7. The apparatus of any one of claims 4 to 6, wherein said pulse modulated signal is a pulse width modulated (PWM) signal, said PWM signal having a duty cycle that can be selectively changed to change light intensity from the lamp.

8. The apparatus of any one of claims 4 to 7, wherein said actuating means varies duty cycle of said signal as a function of the light intensity from the lamp.

9. The apparatus of any preceding claim, wherein the lamp is differentially energized by said power supply.

10. The apparatus of claim 9, wherein said power supply comprises a high frequency sine wave inverter including a transformer with secondary windings connected to electrodes of the lamp.

11. The apparatus of claim 1, wherein said control circuit comprises a solid state switch in shunt with the lamp, said solid state switch being operated as a class A device using a pulse modulated control signal having a duty cycle that can be varied to change the average current through the switch.

12. The apparatus of claim 1, wherein the lamp current is sinusoidal and said control circuit comprises an AC switch in shunt with the lamp to vary the average current through the lamp.

13. The apparatus of claim 12 wherein said switch is controlled by a pulse modulated control signal that is synchronous with the lamp current frequency, and has a frequency substantially less than said current frequency and higher than a frequency detectable by an observer of the lamp output intensity.

14. A method for controlling intensity of a fluorescent lamp, comprising the steps of:

a) producing a voltage at the output of a power supply to energize the lamp; and

b) shunting current away from the lamp to reduce the output intensity of the lamp.

15. The method of claim 14, wherein the step of shunting current from the lamp comprises the steps of actuating a solid state switch in shunt with the lamp such that when the switch is turned on less current flows through the lamp, said switch being actuated with a pulse width modulated signal having a duty cycle that determines the output intensity of the lamp by controlling the average current shunted by said switch.

16. The method of claim 15, wherein the lamp is driven by an AC voltage and the step of actuating said switch with a pulse width modulated signal is performed by synchronizing said pulse width modulated signal with said AC voltage.

17. Apparatus for controlling the intensity of a fluorescent lamp, the apparatus comprising: a power supply with a voltage output connected to the lamp; and a control circuit that is connected to said output and which operates to selectively reduce light intensity from the lamp by changing

current through the lamp.

18. The apparatus of claim 17, wherein said control circuit comprises a solid state switch in shunt with the lamp; and means for controlling said switch with a pulse width modulated (PWM) signal having a duty cycle that controls time periods during which said switch shunts current from the lamp.

19. The apparatus of claim 18, wherein said voltage output is AC and said PWM signal is synchronous with said AC voltage output.

20. The apparatus of any one of claims 17 to 19, wherein said power supply comprises a self-oscillating inverter and continuously delivers power to said output.

21. The apparatus of any one of claims 17 to 20, wherein said power supply comprises a resonant circuit that produces an output drive current for the lamp; said control circuit operating to control intensity of the lamp by controlling average current through the lamp.

22. The apparatus of claim 21, wherein said control circuit controls average current through the lamp by shunting current away from the lamp and recirculating the power supply output drive current back to the power supply.

23. The apparatus of claim 17, wherein said control circuit comprises a solid state switch in series with said output and the lamp; said solid state switch being actuated by a pulse width modulated (PWM) signal to vary current through the lamp in relation to duty cycle of the PWM signal.

Application No:	GB 9716377.8	**Examiner:**	M J Billing
Claims searched:	1 to 23	**Date of search:**	9 October 1997

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): G3R RBK; H2H HLD52, HLD62, HLD631.

Int Cl (Ed.6): G05D 25/02; G09G 3/34; H05B 41/38, 41/39, 41/392, 41/40, 41/42.

Other: ONLINE - WPI.

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB2269948A	(AXIOMATIC) - Fig.5; Abstract	1-8,11,12, 14-19,23 at least
X	EP0086664A1	(ESQUIRE) - Figs.1-3	1,2,4,5,6, 7,12,17,23 at least
X; Y	WO82/03744A1	(KOCH) - Figs.1-5; Abstract	1-5,7,11, 13-19; 9,10,20-22 at least
X	US5175471	(DIEHL) - Fig.s1-5; Abstract, column 4 lines 37-51	1-7,11-19 at least
X	US4749916	(MITSUBISHI) - Figs.2,3,6,12,13,14	1-4,7, 9-12, 14,15,17, 18,20-23 at least
X	US4682083	(GENERAL ELECTRIC) - Figs.1,8; Abstract	1-5,7,11, 12,14-19, 23 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

The Patent Office

19

Application No: GB 9716377.8
Claims searched: 1 to 23
Examiner: M J Billing
Date of search: 9 October 1997

Category	Identity of document and relevant passage	Relevant to claims
Y	US4544862 (MITSUBISHI) - Figs.3,7,9	9,10,20-22 at least
X; Y	IBM Technical Disclosure Bulletin, Vol.34 No.4A, September 1991, pages 109-111, "Simple dimming circuit for fluorescent lamp".	1-5,7,11, 13-19; 9,10,20-23 at least

X Document indicating lack of novelty or inventive step
Y Document indicating lack of inventive step if combined with one or more other documents of same category.
& Member of the same patent family
A Document indicating technological background and/or state of the art.
P Document published on or after the declared priority date but before the filing date of this invention.
E Patent document published on or after, but with priority date earlier than, the filing date of this application.